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(54) REDUCED PULSATION TAPERED RAMP PUMP HEAD

PUMPENKOPF MIT VERJÜNGENDER RAMPE ZUR PULSATIONSREDUZIERUNG

POMPE A ELEMENT CONIQUE OFFRANT UNE PRESSION DE REFOULEMENT A PULSATION REDUITE

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- **PISULA 'tubing for peristaltic pumps' 26 May 1988 , MACHINE DESIGN , CLEVELAND**

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Description

The present invention generally relates to peristaltic pumps and more particularly to precision peristaltic pumps, particularly suitable for the simultaneous removal (aspiration) of irrigation fluids in an eye cavity during ophthalmic surgery as, for example, for the removal of cataracts.

The necessity for precisely controlling pressure in the eye during surgery is well-known. During surgery on normally pressurized eyes, instruments are passed through a small incision of the cornea in order to access and remove a natural lens which has become opaque from a cataract.

Cataracteous lens may be broken up by cutting apparatus or by ultrasonic apparatus and the fractured material aspirated, together with a quantity of aqueous irrigation fluid in the eye chamber.

The removed irrigation fluid is simultaneously replaced in order to maintain a normal pressure in the eye.

While pressure may be controlled by a pressure regulation device, greater pressure stability nay be assured through the use of a pump having minimal back pressure or pump pulsations.

Severe reductions in the eye pressure will result in collapse of the eye chamber, but aside from these traumatic results, the maintenance of proper pressure within an eye during surgical procedures is important to preserve and stabilize the spatial relationships of the intraocular tissues. Thus, variations of pressure during an operation may impair the surgeon's ability to observe and operate on intraocular tissues.

Peristaltic pumps having the features set forth in the preamble to claim 1 appended hereto are disclosed in EP-A-0 019 818 in the name of Siemens.

The present invention provides a peristaltic pump having significantly reduced pump pulsations and therefore particularly suitable for use in surgical procedures such as those hereinabove described.

SUMMARY OF THE INVENTION

A peristaltic pump in accordance with the present invention has the features set forth in claim 1 below.

A peristaltic pump in accordance with the present invention includes a plurality of tube compression means for compressing and sealing a collapsible and resilient tube. Housing means is provided for guiding the collapsible and resilient tube to and from the tube compression means and means are provided for causing the plurality of tube compression means to successively contact, gradually compress and seal the compressible and resilient tube and thereafter gradually uncompress the tube in order to move a fluid through the tube in one direction without creating substantial fluid back pressure in the opposite direction.

More particularly, the plurality of tube compression means comprise a plurality of rollers and the means for causing the plurality of tube compression means to contact, compress and seal the tube comprises a pump arm, having an arcuate surface, and mounted to the housing means in a position enabling the rollers to contact, compress and seal the tube.

Still more particularly, the peristaltic pump in accordance with the present invention further includes assembly head means for supporting the plurality of rollers in a circular pattern about an assembly head axis with each roller having a rotation axis generally parallel to the assembly head axis.

Specifically, the arcuate surface is configured and the pump arm position with respect to the assembly head so that as the assembly head is rotated, each roller successively contacts the tube, gradually compresses and seals the tube during an approximate 45° rotation of the assembly head. Additionally, the arcuate surface is configured with the pump arm position with respect to the assembly head so that each roller successively releases the tube during a rotation of the assembly head about 45°.

The arcuate surface is configured and the pump arm positioned with respect to the assembly head so that each roller maintains a sealing engagement with the tube during approximately a 45° rotation of the assembly head.

In order for uniformly sealing the tube as the roller compresses the tubing, each roller includes a specific circumferential surface thereon. Particularly, each roller has an inside diameter that is smaller than a roller diameter at each end of the roller, and this smaller diameter may be constant between end diameters on each roller, with the end diameters interconnected with the constant diameter by an arcuate surface.

In combination, the present invention also includes a collapsible resilient tube which includes means for preventing movement of the tube itself through the housing means. Particularly, the means for preventing movement of the tube may include at least one collar disposed on the tube having a diameter sufficient to prevent entry of the collar into the housing means.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages and features of the present invention will be better understood by the following description when considered in conjunction with the accompanying drawings in which:

Figure 1 is a perspective view of an assembled peristaltic pump in accordance with the present invention;

Figure 2 is a perspective exploded view of the peristaltic pump shown in Figure 1;

Figure 3 is a cross-section view of the peristaltic pump in accordance with the present invention

showing a plurality of rollers for compressing a resilient tube against a pump arm arcuate surface;

Figure 4 is a cross-section of a prior art peristaltic pump showing the relationship between the rollers and the pump arm arcuate surface;

Figure 5 is a cross-section view of a roller in accordance with the present invention taken along the line 5-5 shown in Figure 3;

Figure 5a is a cross-section veiw of a prior art roller for a. peristaltic pump showing incomplete sealing of a tube;

Figure 6 is a plot of vacuum pressure as a function of time for both a prior art peristaltic pump and a peristaltic pump in accordance with the present invention, showing in comparison a significant reduction in back pressure during operation of the peristaltic pump made in accordance with the present invention operating at flow rate of about 10 ccs per minute; and

Figure 7 is a plot similar to the plot shown in Figure 6 showing the vacuum as a function of time for both prior art pumps and a pump in accordance with the present invention at a flow rate of about 40 ccs per minute.

DETAILED DESCRIPTION OF THE DRAWINGS

Turning now to Figures 1 and 2, there is shown a peristaltic pump 10 in accordance with the present invention generally including an assembly head 26 which provides a means for supporting a plurality of rollers 28 with the latter providing compression means for compressing and sealing a collapsible and resilient tube 32 against an arcuate surface 34 on a pump arm 36.

The pump arm 36 is pivotally mounted to a housing 40 by means of a pin 42 and washer 44 for enabling movement thereof to facilitate insertion and removal of the tube 32. Apertures 46 48 in the housing 40 enable the housing to provide means for guiding the collapsible and resilient tube 32 to and from the arcuate surface 34 and rollers 28.

A spring 52 loaded latch 54 pivotally mounted to the pump arm 36 by a pin 55 enables locking of the pump arm 36 to the housing after insertion of the tube 32 through the apertures 46 and 48, and during operation of the pump. This locking is enabled by the tongue 56 which snaps over a recess 58 in the housing 40, securing a front housing wall 60 between the tongue 56 and a rear portion 62 of the latch 54.

The assembly head 26 is rotatably attached to the housing 40 by way of an axle 68 which passes through bearings 70, 72, a bore 76 in the housing 40 and a hub 78 and coupling 80. The axle 68 is retained in position by a clip 82 in a conventional manner along with a set screw 86.

As will be hereinafter discussed in great detail, the pump arm 36 with arcuate surface 34 is positioned with respect to the assembly head rollers 28 to provide a means for gradually compressing and sealing the collapsible and resilient tube 32 and thereafter gradually uncompressing the tube 32 in order to move a fluid (not shown) through the tube 32 in a direction indicated by the rotation area 92 without creating substantial fluid back pressure in a direction opposite that of the arrow 92. The spatial relationship provided by the mounting of the assembly head 26 and arcuate surface 32 is more clearly shown in Figure 3.

It should be appreciated that while four rollers 28 are shown mounted in a circular pattern about an assembly head axis 96, a larger or smaller number of rollers may be suitable depending upon pumping requirements. As shown each roller 28 includes a roller axis 100 which is generally parallel to the assembly head axis 96.

As shown in Figure 3, the arcuate surface 34 is configured and the pump arm 36 positioned with respect to the assembly head 26 so that as the assembly head 26 is rotated in the direction of arrow 92, each roller 28 successively contacts the tube 32, gradually compresses and seals the tube 32 during approximately a 45° rotation of the assembly head 26.

Further configuration of the arcuate surface 34 and position of the pump arm 36 with respect to the assembly head 26 enables each roller to gradually release the tube during a rotation of the assembly head 26 of about 45°. This configuration also enables each roller to remain in a sealing engagement with the tube 32 during approximately a 90° rotation of the assembly head 26.

This is to be contrasted with a prior art peristaltic pump 102 in which positioning of prior art assembly heads 104 with pump arm arcuate surfaces 106 is shown in Figure 4. In the prior art arrangement, sealing of the tube 108 occurs in a small angular rotation (In the direction of arrow 110) of the prior art assembly head 104. This results in movement of fluid within the prior art tube 108 away from the compressing prior art roller 112 which causes significant back pressure in the prior art tube 108 as indicated by the arrow 114.

To further enhance the efficient and reliable sealing of the tube 32 by the rollers 28 in the pump 10, according to the present invention, a specific circumferential surface 116 on the rollers 28 is provided, as shown in Figure 5.

As shown, each roller 28 has an inside diameter 118 which is smaller than roller diameters 120 at each end 122, 124 of each roller. This inside diameter 118 is constant between the end diameters 120 and the end diameters 120 are interconnected with the inside diameter 118 by arcuate surface 126.

This generally U-shaped cross-section of the roller provides for uniform sealing tube 32 as shown in Figure

5 which is not possible with a flat or uniform diameter roller 130, see Figure 5a. As shown in cross-section in Figure 5-A, the prior art roller 130 provides incomplete sealing of a tube 132 because the circular nature of the tube inside diameter results in end voids 134 136 unless sufficient pressure is exerted to collapsible the tube side 138.

However, such increased pressure by the rollers 112 may lead to excessive tube wear and may further result in a excess loading on the assembly head 104 and rollers 112.

In order to prevent movement of the tube 32 through the housing 40, collars 144 146 may be attached or molded into the tube at a spaced apart distance from one another in order that each collar is positioned abutting the housing front 40 upon assembly of the tube 32 into the housing 40 and around the rollers 28. The collar diameter is chosen in order to prevent entry of the collar into the housing means 40. It has been found that reliable and efficient performance of the pump is provided when the compressible and resilient tube is formed from silicon having a hardness of about 55 durometers, Shore A, platinum or peroxide cure method, and a typical tubing size is three-eighth inch. Preferably the tube is formed from a peroxide cure silicon, said cure being well known in the art.

This size tube enables pumping volumes of up to about 40 cc/minute when the assembly head is rotated at up to about 75 rpm.

The hereinabove described arrangement of the assembly head 26, rollers 28, and pump head 36 with arcuate surface 34 using the hereinabove referenced tube 32 configuration enables a significant reduction in back pressure as compared to a prior art peristaltic pump 102 having the same overall dimensions and operated at the same volume output. This is clearly shown in Figures 6 and 7 which are plots of the vacuum drawn by the pump as a function of time for pumping volumes of about 10 cc per minute and 40 cc per minute.

Curves A in both Figures 6 and 7 represent the prior art pump performance while Curves B in Figures 6 and 7 represent the results of a peristaltic pump configured in accordance with the present invention.

It can be easily seen from Figure 6 that the vacuum variation on the intake of the pump 10 in accordance with the present invention operating at about 10 ccs per minute is less than plus or minus 4 mm Hg at a vacuum of about 18 mm Hg. This is to be compared with the vacuum variation on the intake of the prior art pump 102 which is about plus or minus 8 mm Hg at 10 ccs per minute. Thus the change in back pressure of the pump 10 in accordance with the present invention over the prior art pump 102 is a factor of two.

An even greater inprovement in reduced vacuum variation or back pressure is exhibited by the pump 10 in accordance with the present invention when operating at a higher flow rate. This is shown in Figure 7 wherein the variation of vacuum for the pump 10 is about plus or minus 5 mm Hg whereas the variation of vacuum for the prior art pump 102 is about plus or minus 15 mm Hg. A factor of about 3 improvement.

Although there has been hereinabove described a specific peristaltic pump in accordance with the present invention, for the purpose of illustrating the manner in which the invention may be used to advantage, it should be appreciated that the invention is not limited thereto. Accordingly, any and all modifications, variations, or equivalent arrangements which may occur to those skilled in the art, should be considered to be within the scope of the present invention as defined in the appended claims.

Claims

1. A peristaltic pump (10) comprising:

   assembly head means (26) for supporting a plurality of rollers (28), said rollers (28) being mounted in an arcuate pattern about an assembly head axis (96), each roller (28) having a rotation axis generally parallel to the assembly head axis (96);
   a collapsible and resilient tube (32);
   housing means (40) for rotatably mounting said assembly head (26) and for guiding the collapsible and resilient tube (32) over said rollers (28);
   a pump arm (36) having an arcuate surface (34), the radius of which arcuate surface (34) is greater than the corresponding radius of the arc of travel of the rollers (28), the pump arm (36) being mounted to said housing means (40) in a position enabling said rollers (28) to compress the tube (32) against the arcuate surface (34) as the assembly head (26) is rotated, said arcuate surface (34) being shaped and positioned with respect to said assembly head (26) so that as the assembly head (26) is rotated, each roller (28) successively contacts the tube (32) and gradually seals the tube (32) during approximately a 45° rotation of the assembly head (26), said pump arm (36) being pivotally mounted to said housing means (40); and
   means (54) for rigidly positioning and locking the pump arms (36) in a closed position enabling said rollers (28) to compress the tube (32) against the arcuate surface (34), characterised in that said collapsible and resilient tube (32) comprises means for preventing movement of the tube through the housing means, and wherein each roller (28) has an inside diameter (118) that is smaller than roller diameters at each end (122, 124) of each roller (28).

2. The peristaltic pump according to Claim 1 wherein there are four rollers (28).

3. The peristaltic pump according to Claim 1 or Claim 2 wherein each roller (28) comprises means defining a circumferental surface thereon, for uniformly sealing the tube as each roller compresses the tubing.

4. The peristaltic pump according to any one of Claims 1 to 3 wherein said means for preventing movement of the tube (32) comprises at least one collar (144) disposed on said tube and having a dimension sufficient to prevent entry of the collar into the housing means (40).

5. The peristaltic pump according to any one of Claims 1 to 4 wherein each roller (28) has a constant diameter extending between end diameters (122, 124) of each roller (28), said end diameters (122, 124) being greater than said constant diameter.

6. The peristaltic pump according to Claim 5 wherein said end diameters (122, 124) are interconnected with said constant diameter by an arcuate surface (126).

Patentansprüche

1. Peristaltische Pumpe (10) mit:

einer Montagekopfeinrichtung (26) zur Halterung einer Vielzahl von Walzen (28), wobei die Walzen (28) in einem bogenförmigen Muster um eine Montagekopfachse (96) herum befestigt sind und jede Walze (28) eine Drehachse allgemein paralle zur Achse (96) des Montagekopfes aufweist,
einem zusammendrückbaren und elastischen Rohr (32),
einem Gehäuseteil (40) zur drehbaren Befestigung des Montagekopfes (26) und zur Führung des zusammendrückbaren und elastischen Rohres (32) über die Walzen (28),
einem Pumpenarm (36) mit einer bogenförmigen Oberfläche (34), wobei der Radius der bogenförmigen Oberfläche größer als der entsprechende Radius des Bewegungsbogens der Walzen (28) ist und der Pumpenarm (36) an dem Gehäuseteil (40) an einer Position befestigt ist, die es den Walzen (28) ermöglicht, das Rohr (32) gegen die bogenförmige Oberfläche (34) zusammenzudrücken, wenn der Montagekopf (26) in Drehung versetzt wird, wobei die bogenförmige Oberfläche (34) bezüglich des Montagekopfes (26) so geformt und angeordnet ist, daß bei der Drehung des Montagekopfes (26) jede Walze (28) aufeinanderfolgend mit dem Rohr (32) in Berührung kommt und das Rohr (32) graduell während einer Drehung von angenähert 45° des Montagekopfes (26) abdichtet, wobei der Pumpenarm (36) schwenkbar an dem Gehäuseteil (40) befestigt ist, und
einer Einrichtung (54) zur starren Positionierung und Verriegelung der Pumpenarme (36) in einem geschlossenen Zustand, in dem es den Walzen (28) ermöglicht wird, das Rohr (32) gegen die bogenförmige Oberfläche (34) zusammenzudrücken,

dadurch gekennzeichnet, daß das zusammendrückbare und elastische Rohr (32) Einrichtungen zur Verhinderung einer Bewegung des Rohres durch das Gehäuseteil umfaßt und daß jede Walze (28) einen innenliegenden Durchmesser (118) aufweist, der kleiner als die Walzendurchmesser an jedem Ende (122,124) jeder Walze (28) ist.

2. Peristaltische Pumpe nach Anspruch 1, bei der vier Walzen (28) vorgesehen sind.

3. Peristaltische Pumpe nach Anspruch 1 oder 2, bei der jede Walze (28) Einrichtungen zur Ausbildung einer Umfangsoberfläche auf dieser Walze zur gleichförmigen Abdichtung des Rohres umfaßt, während jede Walze das Rohr zusammendrückt.

4. Peristaltische Pumpe nach einem der Ansprüche 1 - 3, bei der die Einrichtung zur Verhinderung einer Bewegung des Rohres (22) zumindest einen Ringwulst (144) umfaßt, der auf dem Rohr angeordnet ist und eine Abmessung aufweist, die ausreicht, um den Eintritt des Ringwulstes in den Gehäuseteil (40) zu verhindern.

5. Peristaltische Pumpe nach einem der Ansprüche 1 - 4, bei der jede Walze (28) einen konstanten Durchmesser aufweist, der sich zwischen Enddurchmessern (122,124) jeder Walze (28) erstreckt, wobei die Enddurchmesser (122,124) größer als der konstante Durchmesser sind.

6. Peristaltische Pumpe nach Anspruch 5, bei der die Enddurchmesser (122,124) mit dem konstanten Durchmesser über eine bogenförmige Oberfläche (126) verbunden sind.

Revendications

1. Pompe péristaltique (10) comprenant :

des moyens formant tête d'assemblage (26) destinés à supporter une pluralité de rouleaux (28), lesdits rouleaux (28) étant montés selon une configuration courbe autour d'un axe de tête d'assemblage (96), chaque rouleau (28)

ayant un axe de rotation généralement parallèle à l'axe de tête d'assemblage (96) ;
un tube comprimable et élastique (32) ;
des moyens formant logement (40) pour monter, de manière rotative, ladite tête d'assemblage (26) et pour guider le tube comprimable et élastique (32) autour desdits rouleaux (28) ;
un bras de pompe (36) présentant une surface en forme d'arc (34), laquelle surface en forme d'arc (34) a un rayon plus grand que le rayon correspondant de l'arc de déplacement des rouleaux (28), le bras de pompe (36) étant monté sur lesdits moyens formant logement (40) dans une position permettant auxdits rouleaux (28) de comprimer le tube (32) contre la surface en forme d'arc (34) alors que la tête d'assemblage (26) est mise en rotation, ladite surface en forme d'arc (34) ayant une forme et étant positionnée par rapport à ladite tête d'assemblage (26) de sorte que, alors que la tête d'assemblage (26) est mise en rotation, chaque rouleau (28) entre successivement en contact avec le tube (32) et ferme progressivement le tube (32) au cours d'une rotation d'environ 45° de la tête d'assemblage (26), ledit bras de pompe (36) étant monté, de manière pivotante, sur lesdits moyens formant logement (40) ; et
des moyens (54) destinés à positionner et verrouiller, de manière rigide, les bras de pompe (36) dans une position fermée permettant auxdits rouleaux (28) de comprimer le tube (32) contre la surface en forme d'arc (34), caractérisée en ce que ledit tube comprimable et élastique (32) comprend des moyens destinés à empêcher le mouvement du tube à travers les moyens formant logement et dans laquelle chaque rouleau (28) a un diamètre intérieur (118) plus petit que les diamètres des rouleaux à chaque extrémité (122, 124) de chaque rouleau (28).

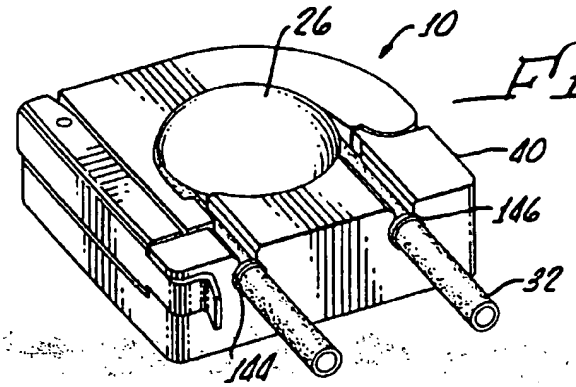
2. Pompe péristaltique selon la revendication 1, dans laquelle il y a quatre rouleaux (28).

3. Pompe péristaltique selon la revendication 1 ou la revendication 2, dans laquelle chaque rouleau (28) comprend des moyens définissant une surface circonférentielle sur celle-ci, pour fermer le tube, de manière uniforme alors que chaque rouleau comprime le tube.

4. Pompe péristaltique selon l'une quelconque des revendications 1 à 3, dans laquelle lesdits moyens destinés à empêcher le mouvement du tube (32) comprennent au moins un collier (144) disposé sur ledit tube et d'une dimension suffisante pour empêcher l'entrée du collier dans les moyens formant logement (40).

5. Pompe péristaltique selon l'une quelconque des revendications 1 à 4, dans laquelle chaque rouleau (28) a un diamètre constant s'étendant entre les diamètres d'extrémité (122, 124) de chaque rouleau (28), lesdits diamètres d'extrémité (122, 124) étant plus grands que ledit diamètre constant.

6. Pompe péristaltique selon la revendication 5, dans laquelle lesdits diamètres d'extrémité (122, 124) sont interconnectés avec ledit diamètre constant par un surface en forme d'arc (126).


26
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40
146
32
144

FIG. 1.

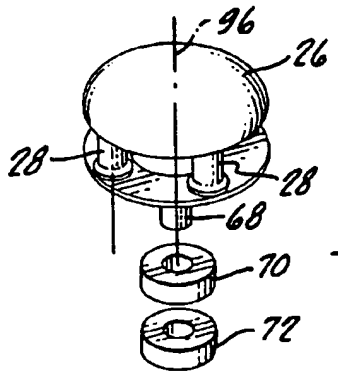
96
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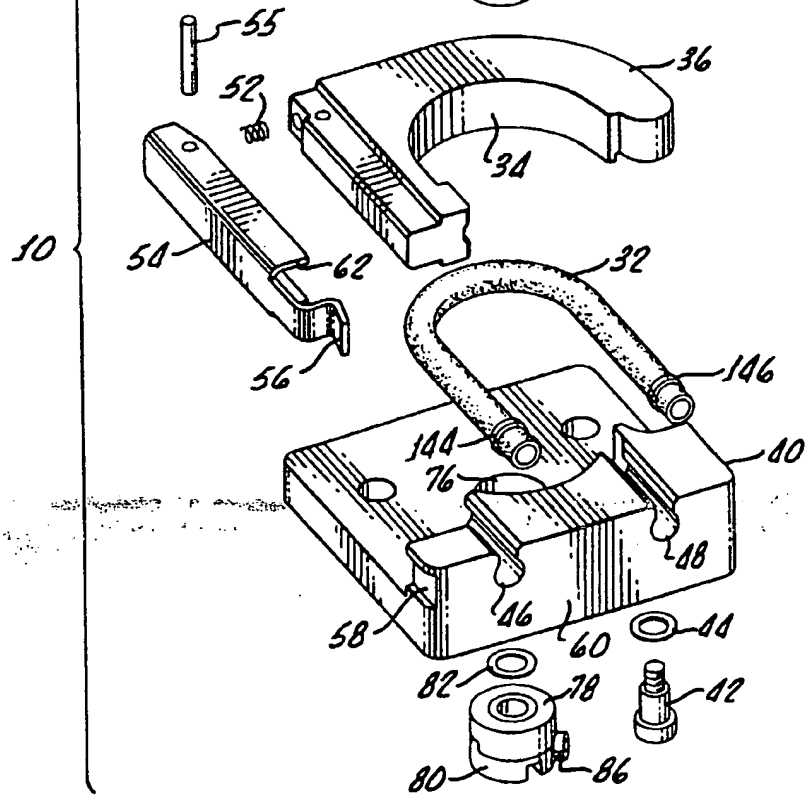
FIG. 2.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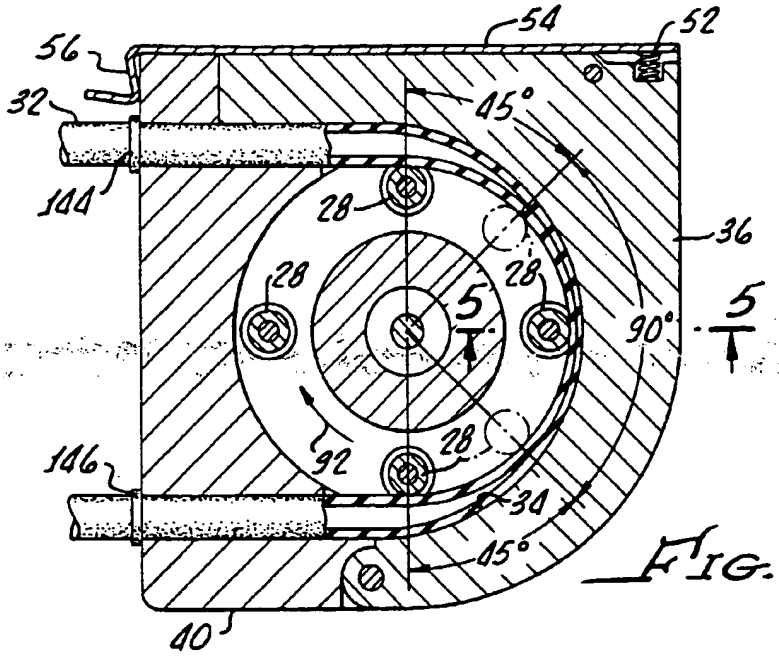


FIG. 3.

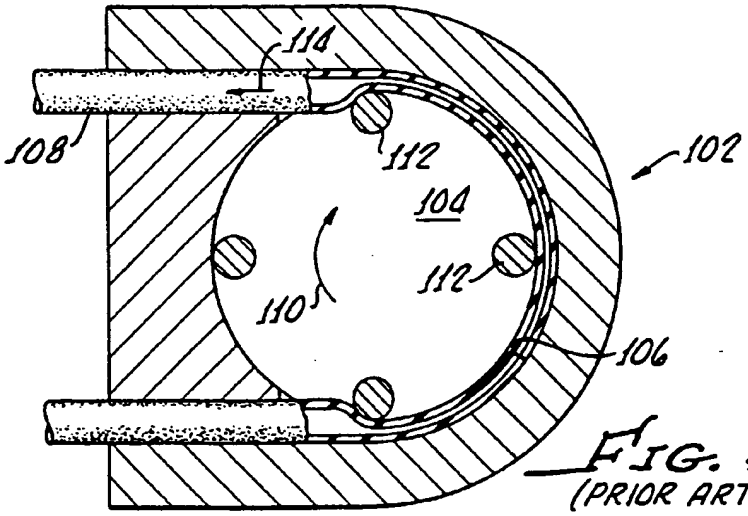


FIG. 4.
(PRIOR ART)

FIG. 5a. (PRIOR ART)

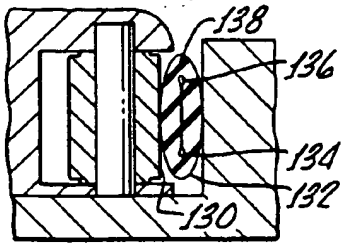


FIG. 5.

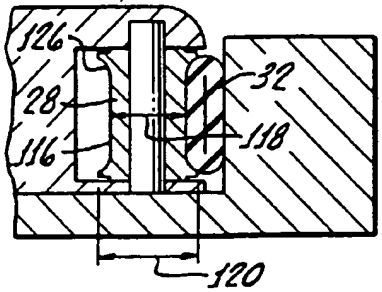
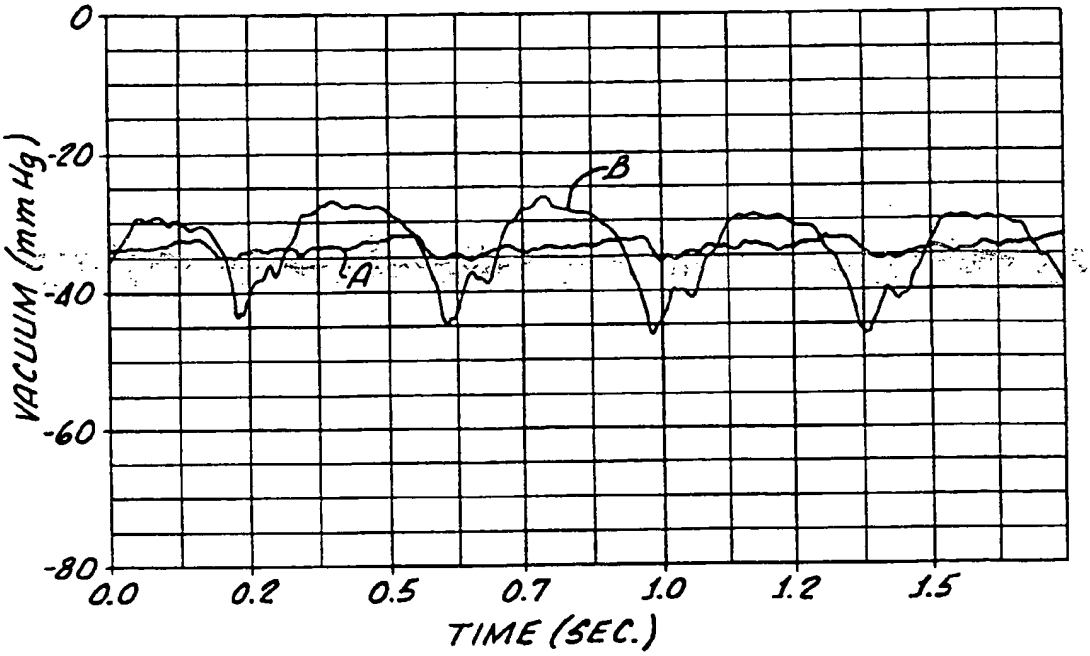


FIG. 6.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-20
-40
-60
-80
VACUUM (mm Hg)
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B
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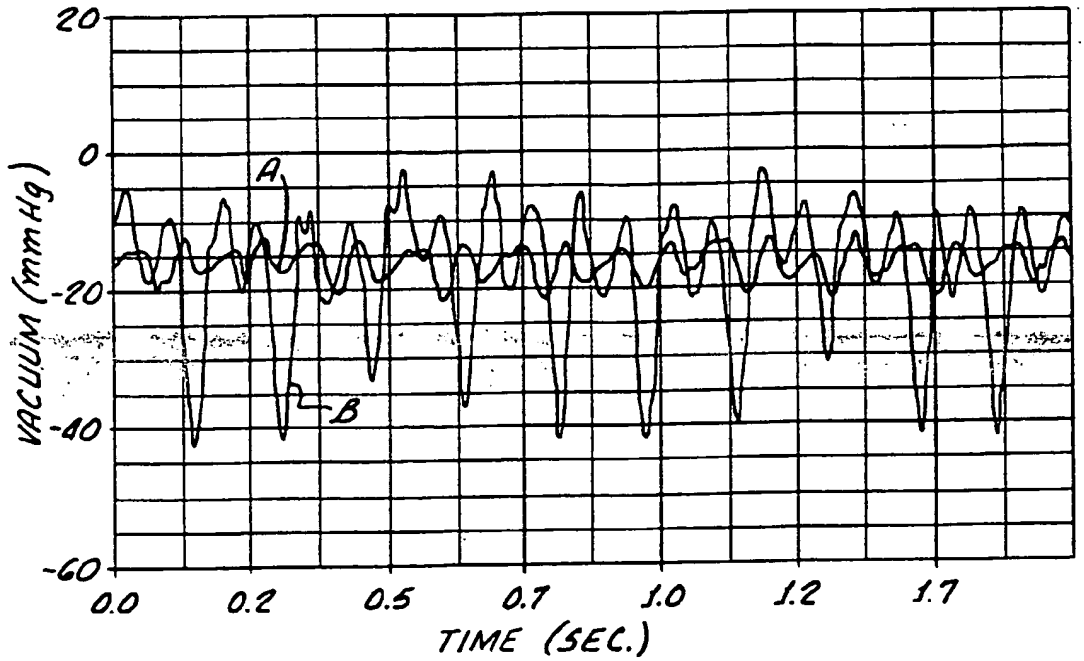
0.2
0.5
0.7
1.0
1.2
1.5
TIME (SEC.)

FIG. 7.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TIME (SEC.)